



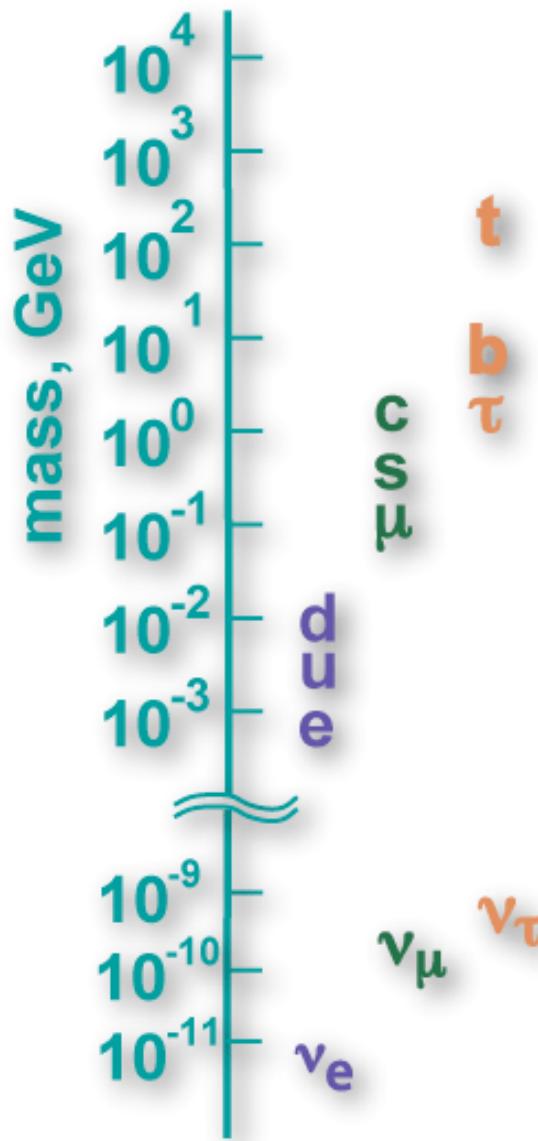
Top Mass at the Tevatron

Jahred Adelman

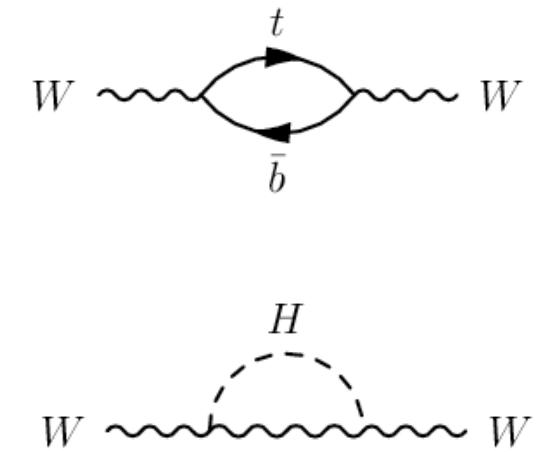
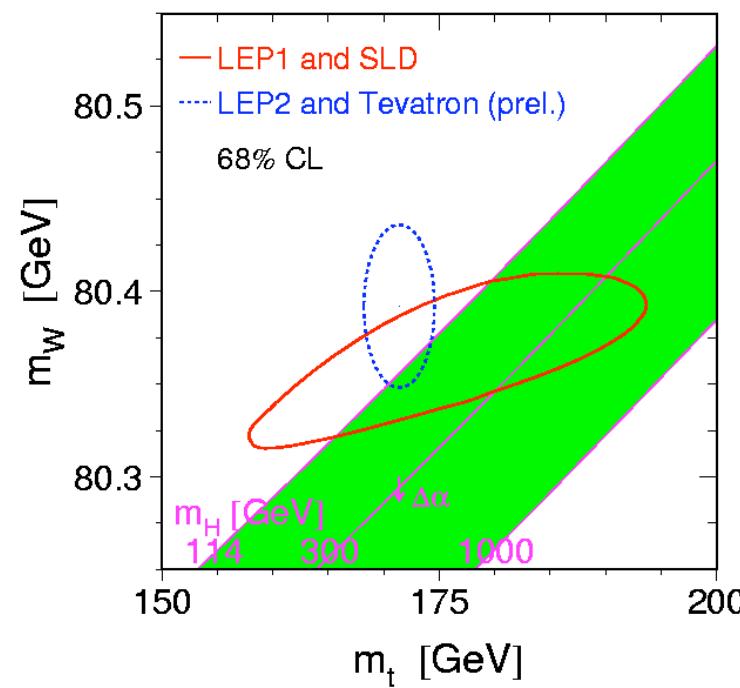
University of Chicago

La Thuile Top Mass

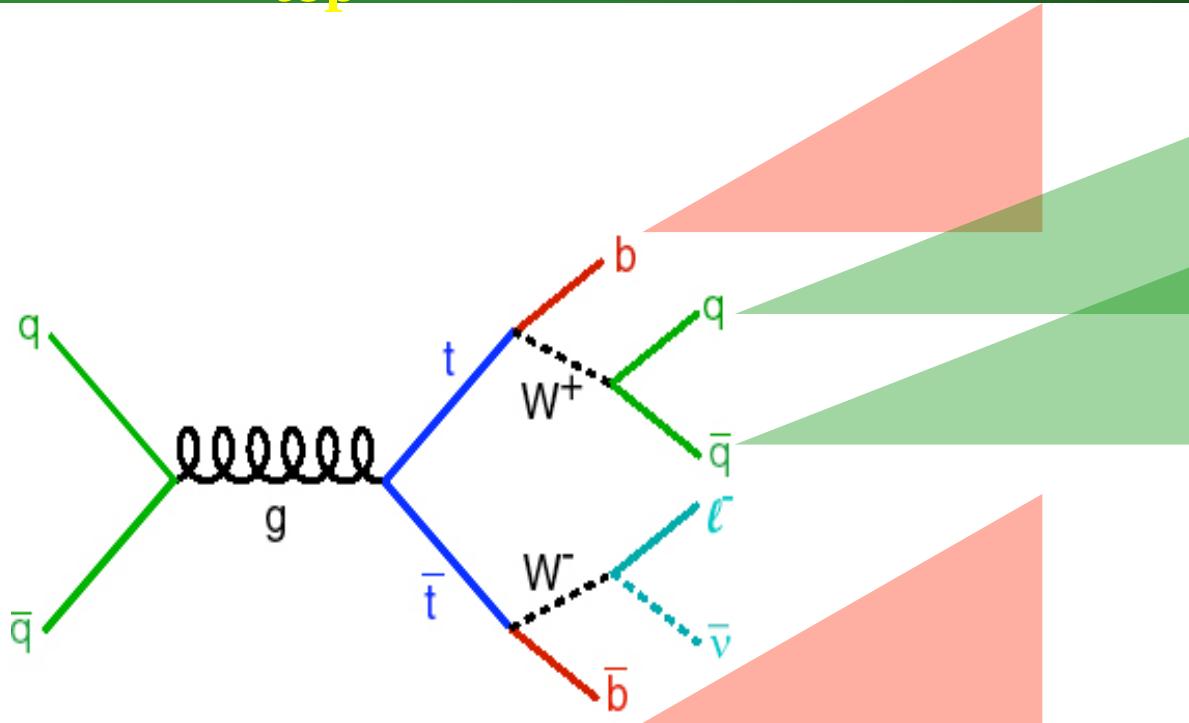
The top quark



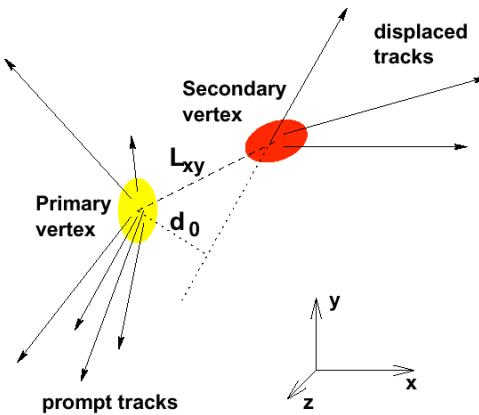
- Top is by far the heaviest known particle
- A role in electroweak-symmetry breaking?
- When we find Higgs, a precision test of the SM



Why M_{top} is difficult

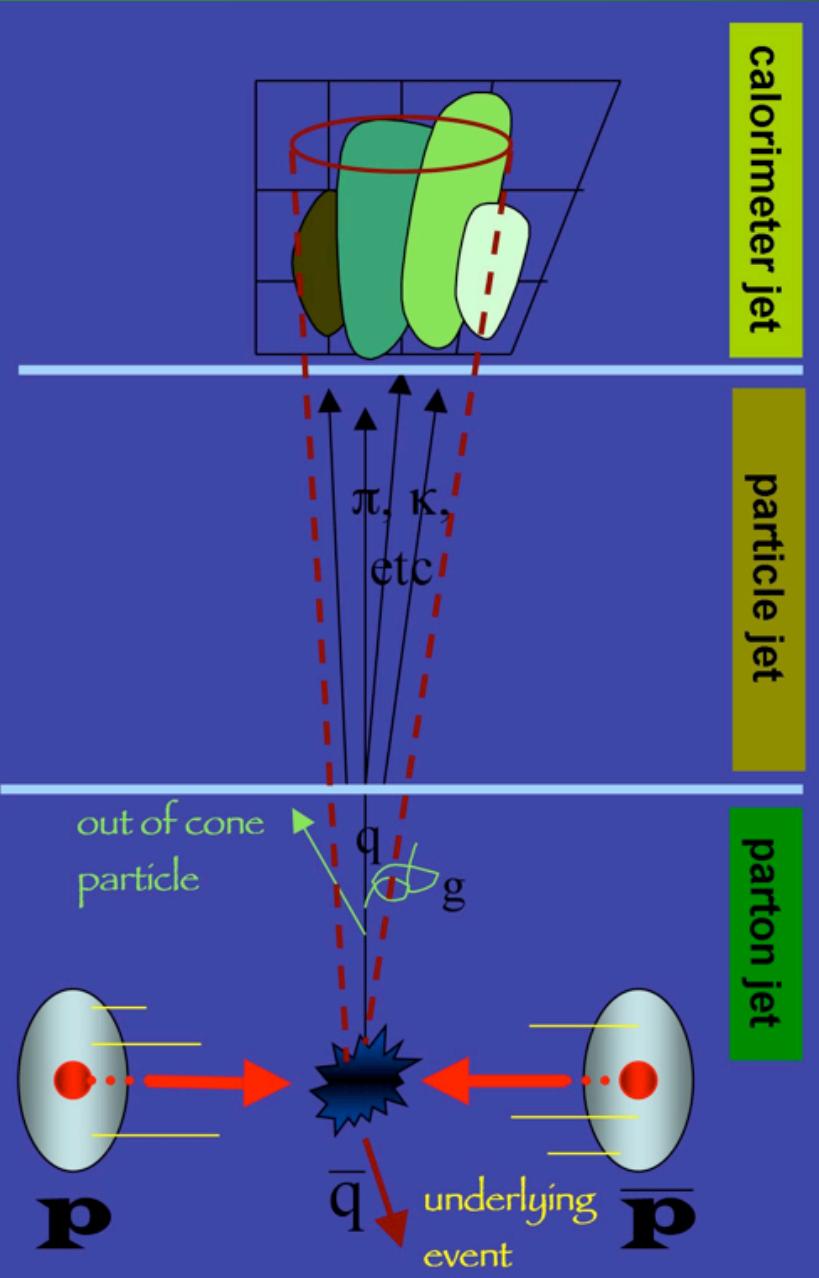


- Tops produced predominantly in pairs
- Decay \sim always to $W+b$
- Topology depends on W decay (hadronic vs leptonic)
- Combinatorics ...
- Up to 6 jets ...
- Up to 2 neutrinos ...

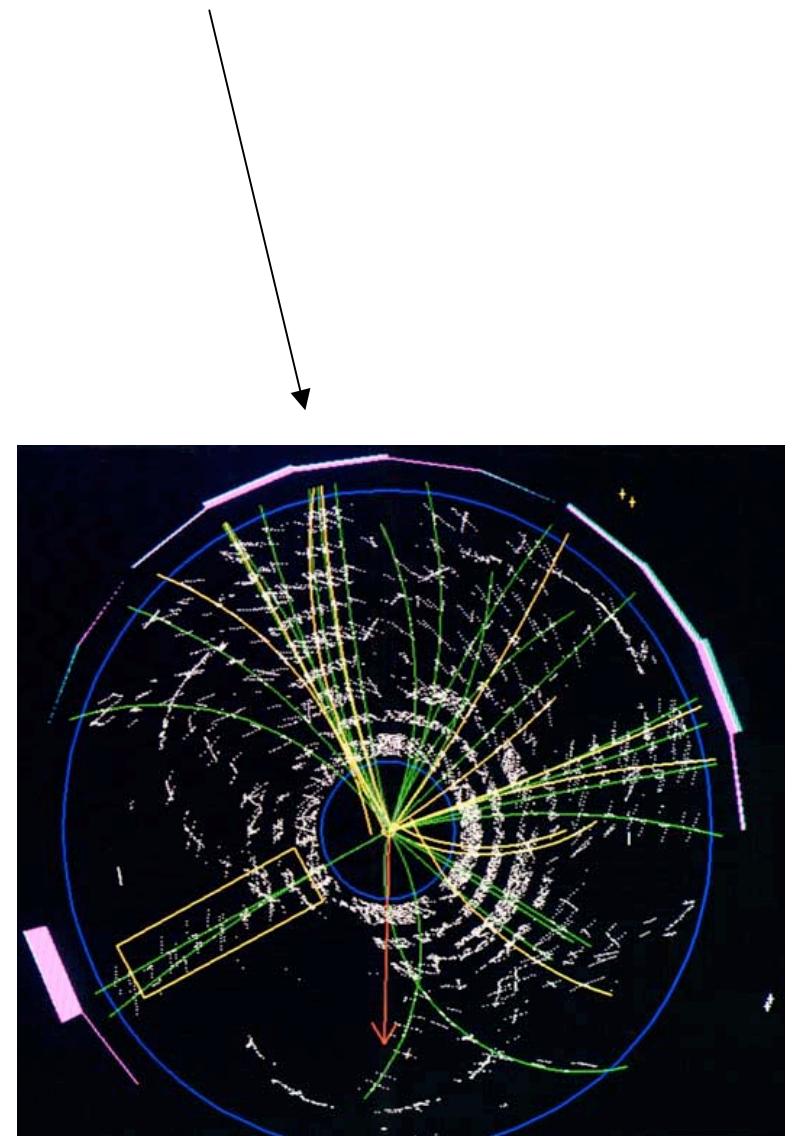


Tagging jets from b quarks reduces combinatorics, cuts away background

Jet Energy Scale (JES)



What we actually see in our detector ...

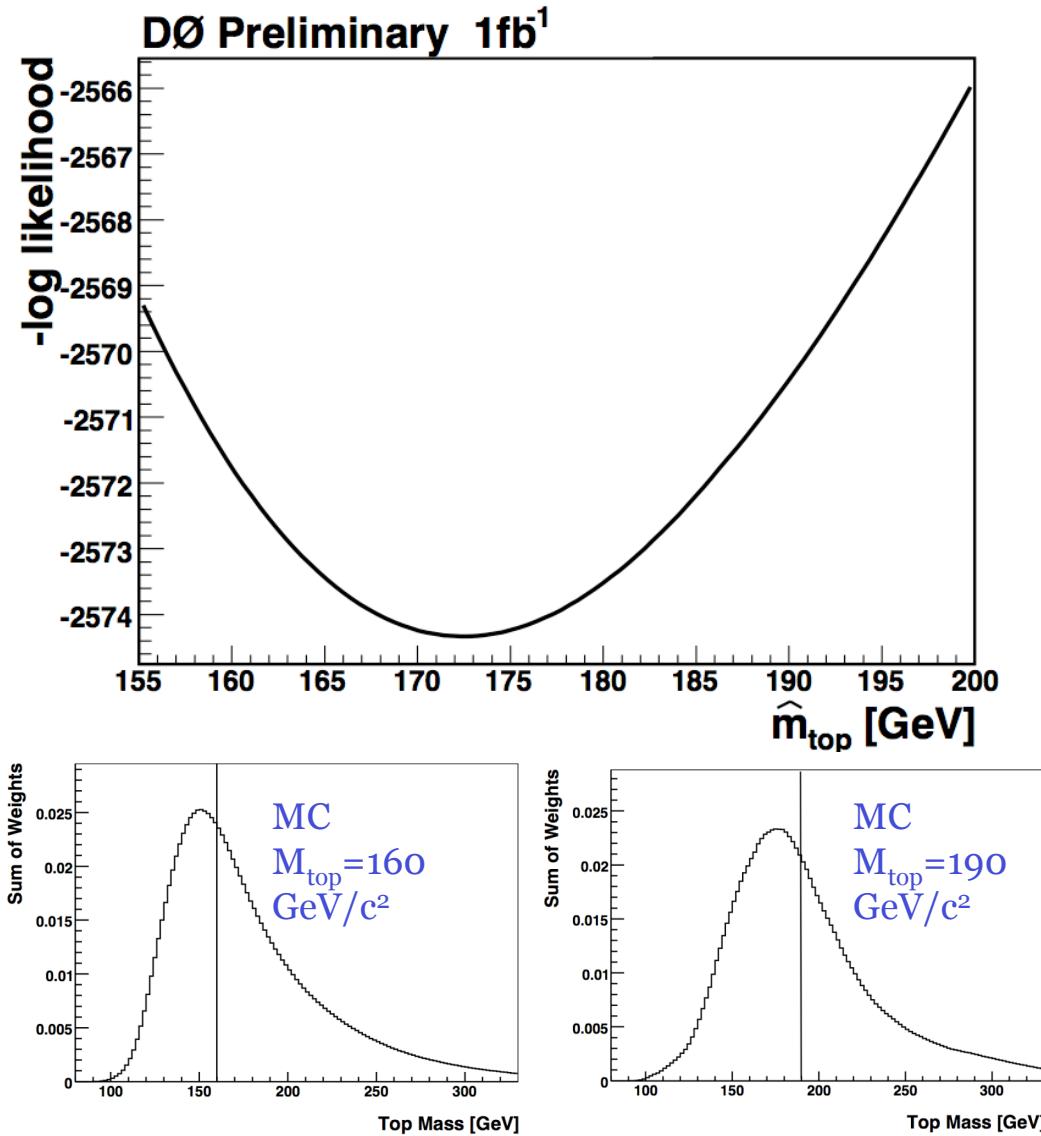


Example of backgrounds

	0-tag	tagged
WW	6.3 ± 1.0	0.2 ± 0.04
WZ	1.5 ± 0.2	0.03 ± 0.00
ZZ	1.1 ± 0.8	0.1 ± 0.1
DY $\tau\tau$	4.3 ± 1.3	0.2 ± 0.1
DY $e e, \mu\mu$	11.7 ± 1.9	0.6 ± 0.1
fakes	5.6 ± 0.4	1.2 ± 0.2
Total Background	30.4 ± 4.1	2.4 ± 0.4
$t\bar{t}$ (6.7 pb)	40.1 ± 3.1	55.8 ± 4.2
	1-tag	2-tag
W $b\bar{b}$	9.1	2.1
W $c\bar{c}$	5.0	0.4
W c	3.3	0.1
W(mistags)	10.4	0.2
single top	2.0	0.7
diboson	2.4	0.2
QCD	10.4	0.3
Total Background	42.7 ± 12.5	4.2 ± 1.9
$t\bar{t}$ (6.7 pb)	156.7	76.6

- Background estimates for CDF template dilepton (top) and Lepton+Jets (bottom) analyses (1.9 fb^{-1})
- Most background shapes/kinematics are MC-based, except for fakes/QCD
- Rates are typically a combination of data and MC
- Requiring a b-tag significantly cuts away background

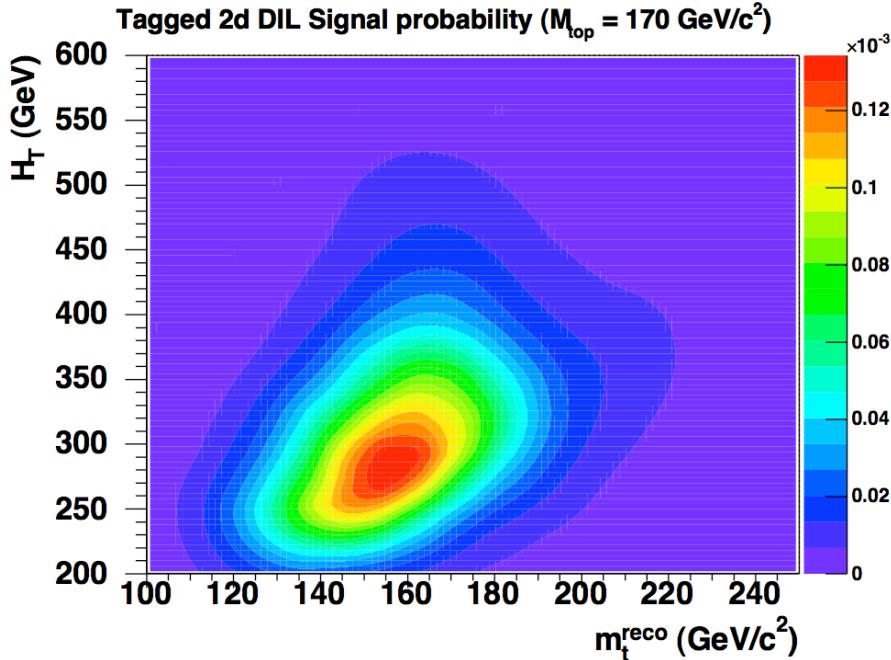
DZero dilepton template measurement



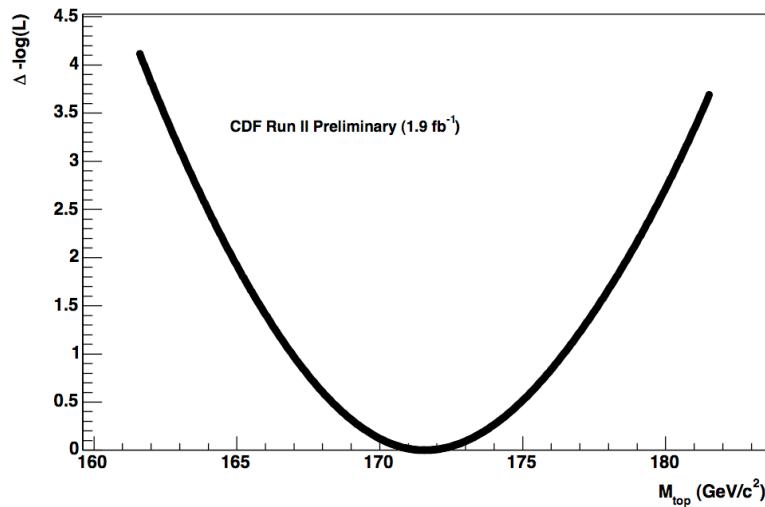
- Neutrino Weighting
Algorithm integrates over unknown pseudorapidities of the two neutrinos, weights solutions by agreement with missing ET (MET)
- Use mean and RMS of weight distributions from MC as estimators
- Systematics dominated by JES

$$M_{\text{top}} = 172.5 \pm 5.8 \text{ (stat)} \pm 3.5 \text{ (syst)} \text{ GeV}/c^2$$

CDF dilepton template measurement



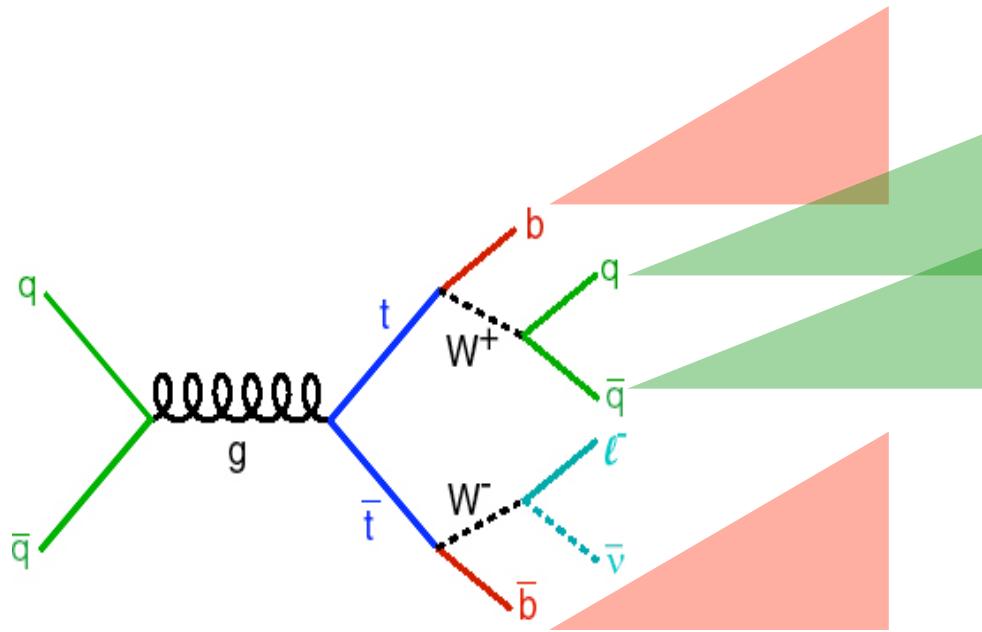
- Also uses Neutrino Weighting Algorithm, selects peak (most probable value) of weight distribution as first observable
- Second observable is the H_T (scalar sum MET, lepton P_T , jet P_T) in the event
- Again limited by JES systematic



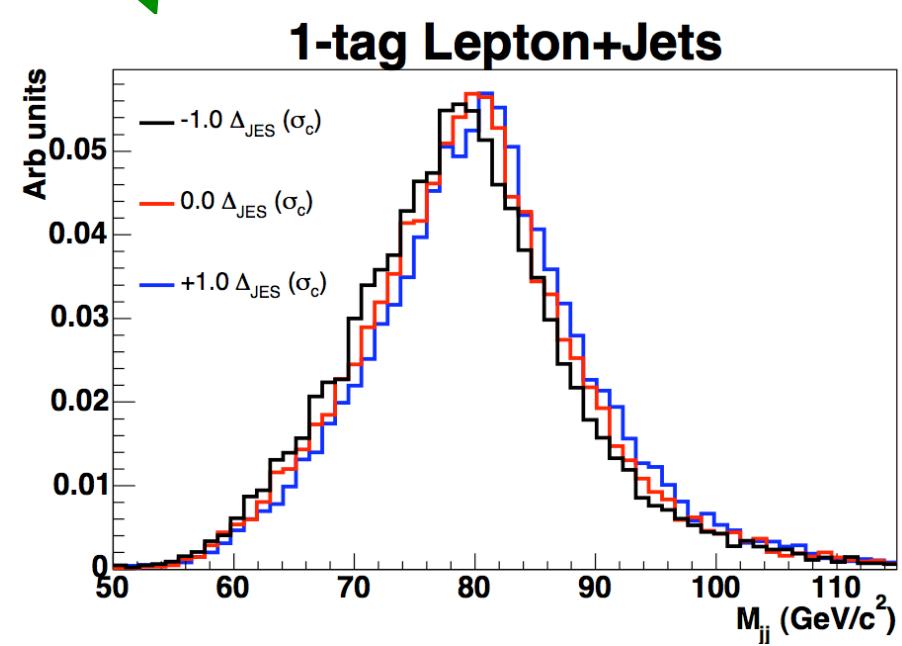
$$M_{\text{top}} = 171.6 +3.4/-3.2 \text{ (stat)} \\ \pm 3.8 \text{ (syst) } \text{GeV}/c^2$$

A handle on the Jet Energy Scale

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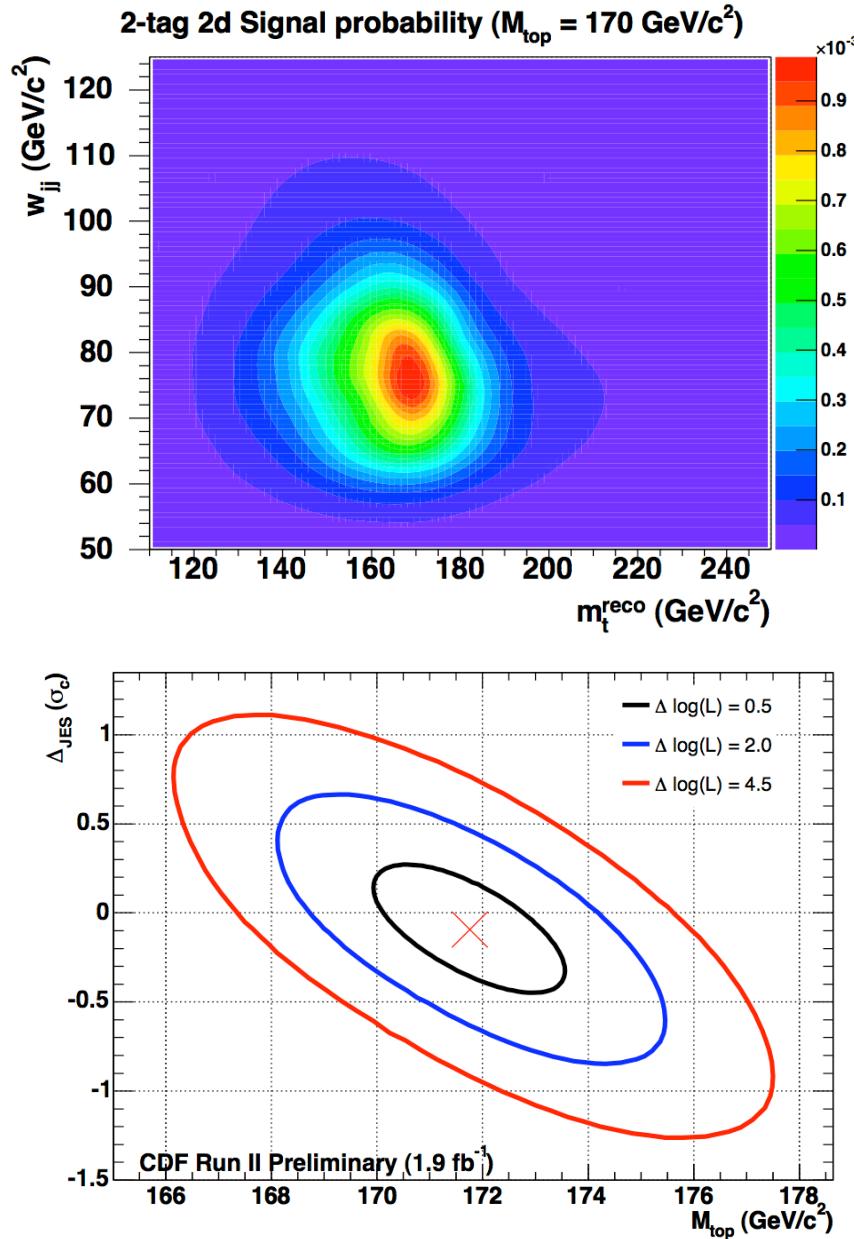


Dijet mass of hadronically decaying W provides *in situ* calibration of JES



CDF Lepton+Jets template measurement

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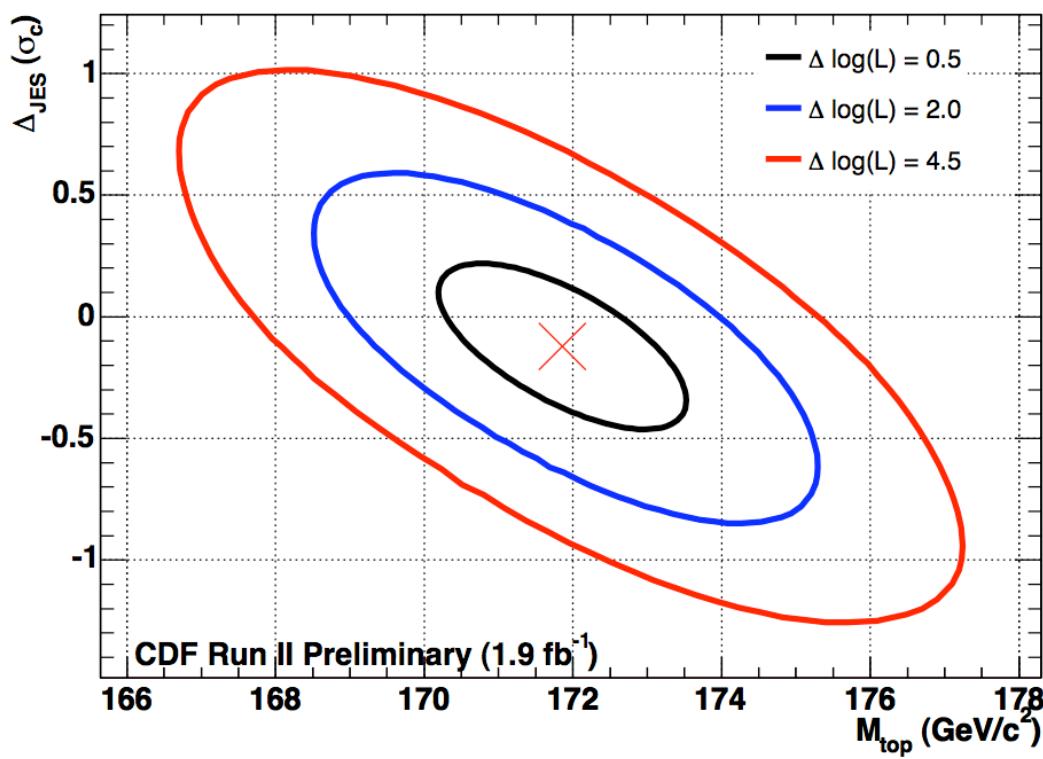


- Form an estimator for the top quark mass using knowledge of overconstrained kinematics (one number per event)
- Use dijet mass of hadronically decaying W as second observable, to constrain JES
- Measure M_{top} while profiling out the largest systematic

$$M_{\text{top}} = 171.8 \pm 1.9 \text{ (stat)} \\ \pm 1.0 \text{ (syst) } \text{GeV}/c^2$$

CDF combined template measurement

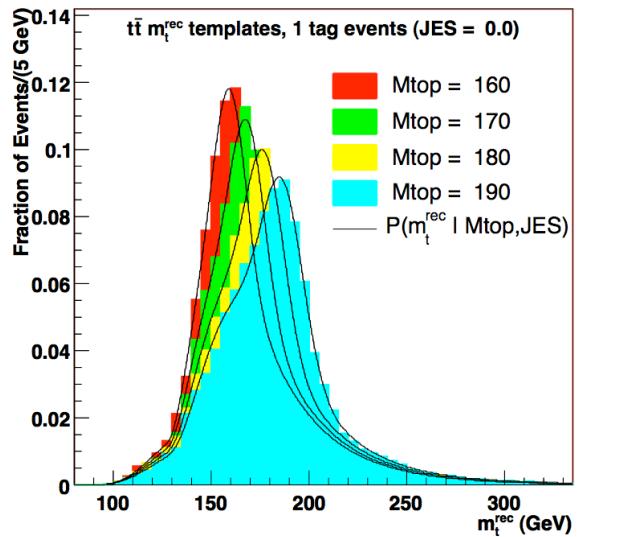
10



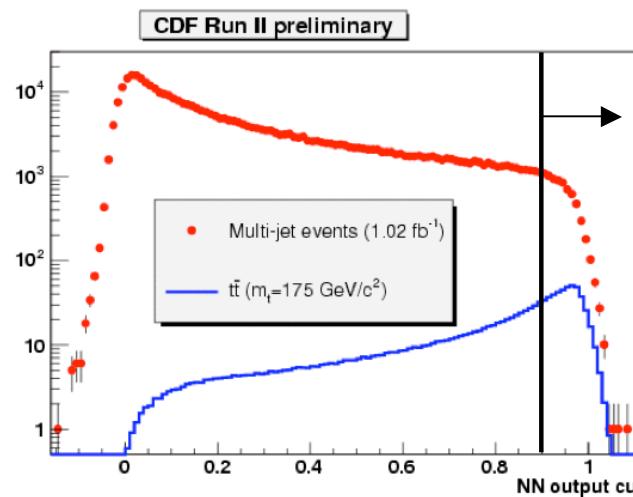
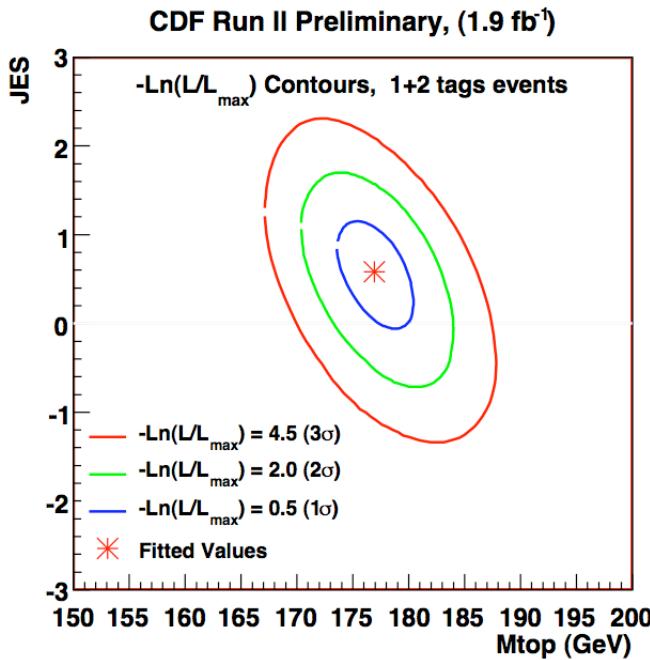
- Combine Lepton+Jets and Dilepton template measurements in the same likelihood
- Robust combination
- No assumptions about correlations for systematics
- Dileptons make use of the Lepton+Jets *in situ* JES calibration

$$M_{\text{top}} = 171.9 \pm 1.7 \text{ (stat)} \pm 1.0 \text{ (syst)} \text{ GeV}/c^2$$

CDF All-hadronic template measurement



- All-hadronic selection with neural network to increase S:B
- Kinematic fitter using knowledge of overconstrained kinematics: one estimator for top quark mass
- Use fitted mass of hadronically decaying Ws to get a handle on JES



$M_{\text{top}} = 177.0$
 $\pm 3.7 \text{ (stat)} \pm$
 1.6 (syst)
 GeV/c^2

Matrix Element Analyses

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- Try to extract as much information as possible from every event using theoretical prediction for ttbar production and decay
- Use all jet-parton combinations, integrate over unknown parton energies given a measured jet energy

$$P(\vec{x}|M_t) = \frac{1}{N} \int d\Phi |M_{t\bar{t}}(p; M_t)|^2 \prod_{\text{objects}} W(p, j) f_{PDF}(q_1) f_{PDF}(q_2)$$

ME for ttbar production and decay

Transfer function: probability to observe jet j given parton p

Parton Distribution Functions for incoming partons

Normalization

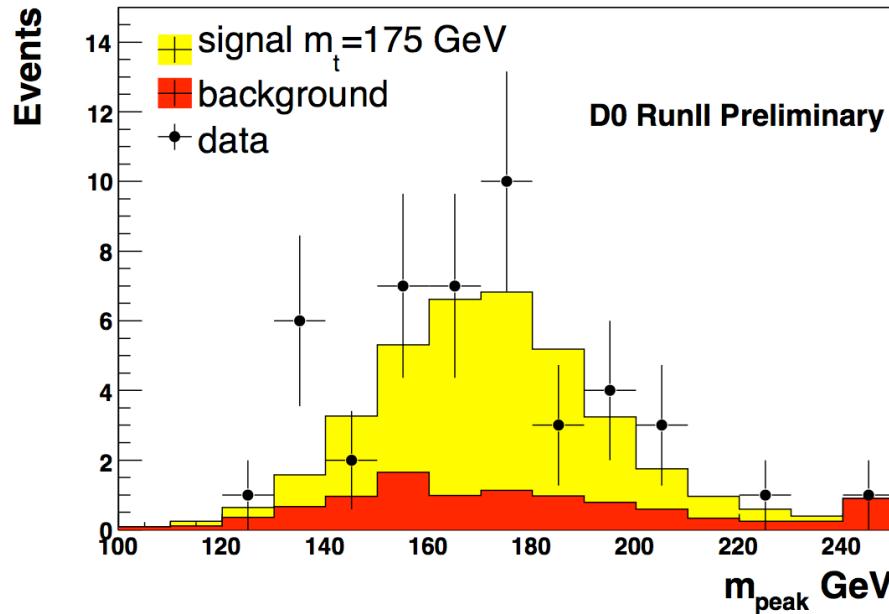
Parton-level phase space

Probability to observe x in detector, given a top quark mass

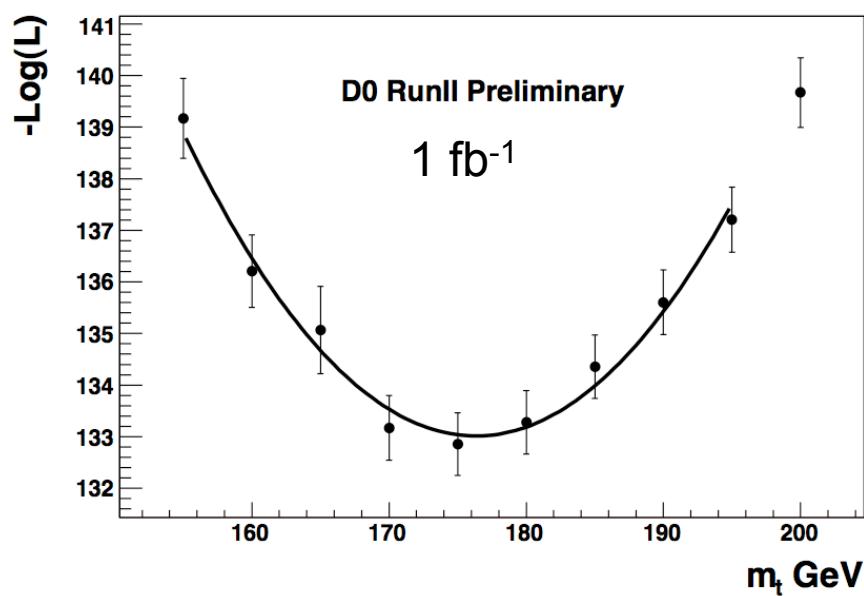
Probability to observe x in detector, given a top quark mass

DZero dilepton ME measurement

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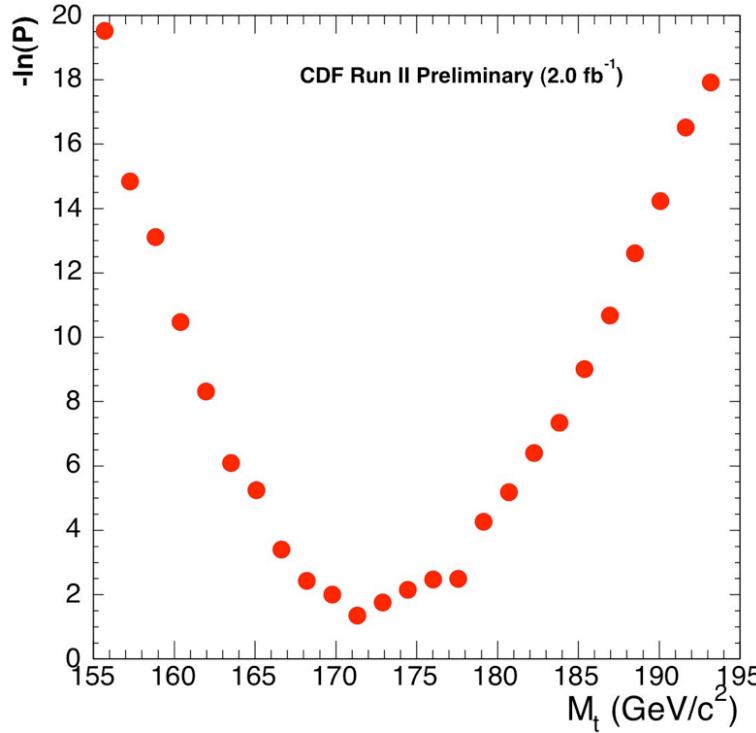
- Each lepton-jet pairing given weight of expectation to find leptons with measured energy, PDFs for initial quark energy
- Jet Energy Scale once again dominates the systematics



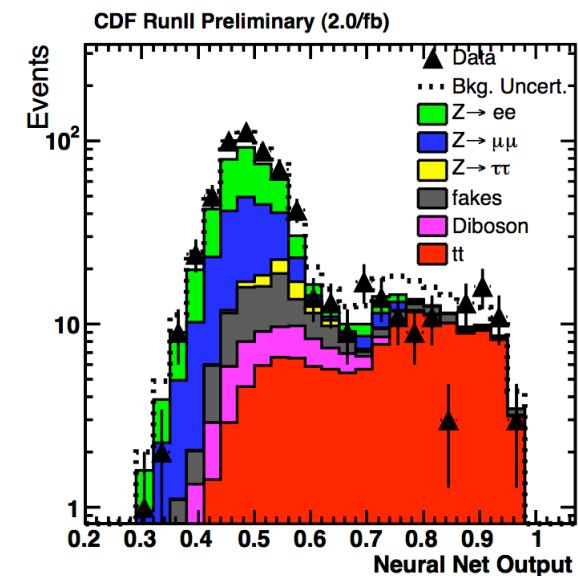
$$M_{\text{top}} = 175.2 \pm 6.1 \text{ (stat)} \\ \pm 3.4 \text{ (syst)} \text{ GeV}/c^2$$

CDF dilepton ME measurement

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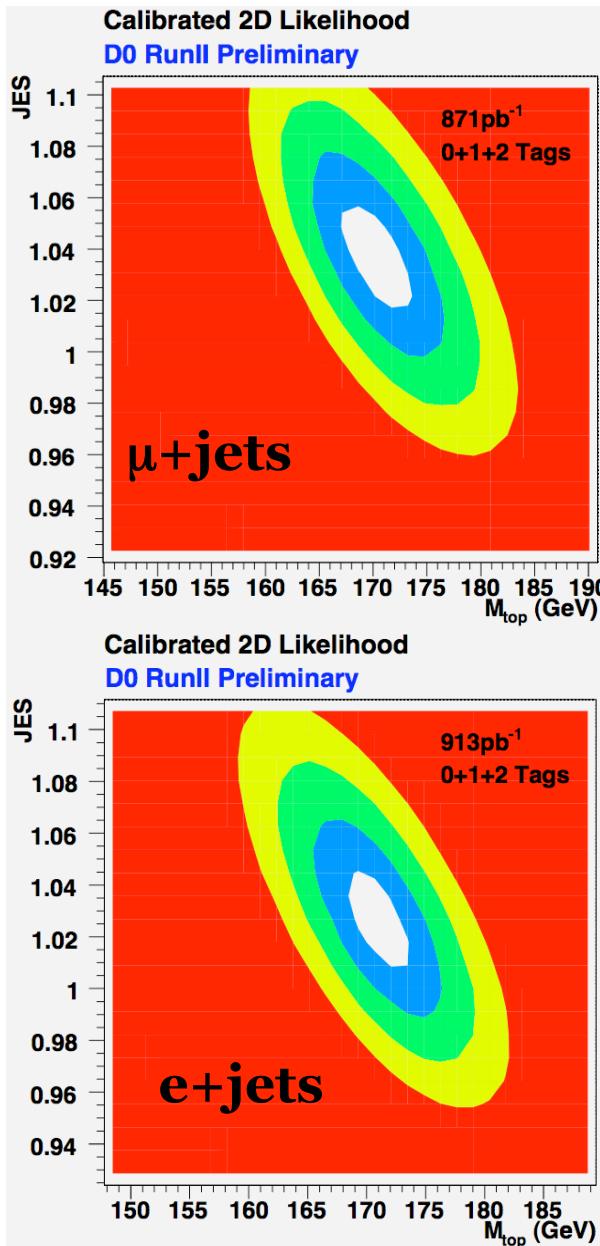
- Revisit event selection via evolutionary neural networks (20% improvement in *a priori* statistical uncertainty)
- JES dominates systematics



$$M_{\text{top}} = 171.2 \pm 2.7 \text{ (stat)} \pm 2.9 \text{ (syst)} \text{ GeV}/c^2$$

DZero Lepton+Jets ME measurement

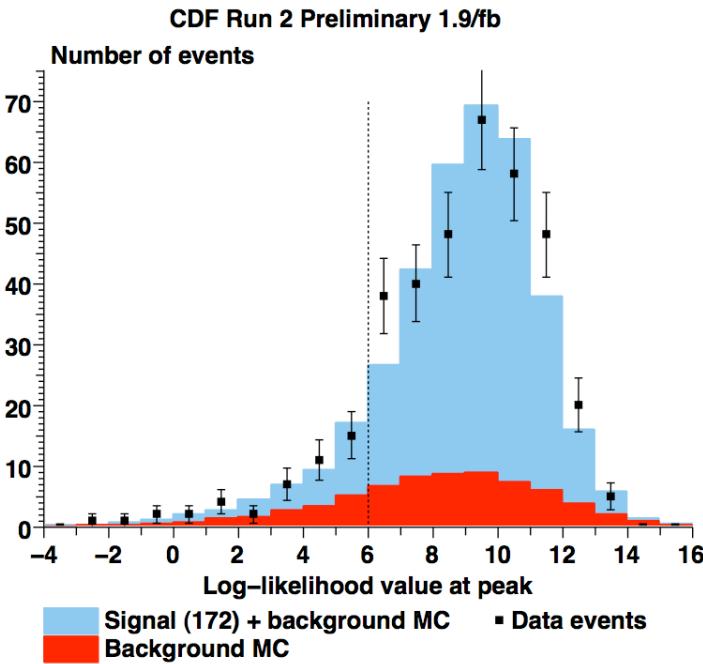
15



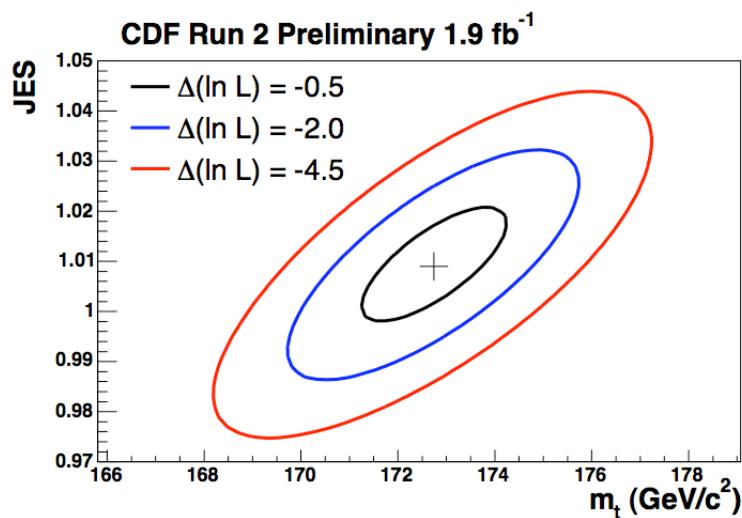
- Weight permutations by b-tagging probability, including 0-tag events
 - Systematics dominated by signal modeling, b-JES
 - Integrate over P_T of $t\bar{t}$ system
 - Measure and then project out the JES

$$M_{top} = 170.5 \pm 2.4 \text{ (stat)} \\ \pm 1.2 \text{ (syst) GeV/c}^2$$

CDF Lepton+Jets ME measurement



- Weight permutations by b-tagging probability, use only tagged events
 - Project out JES
 - Subtract off average background likelihood, weighting by expected background fraction
 - Make peak likelihood cut to remove poorly modeled events (signal+background)
- Modify propagators in matrix element to account for incorrect assumptions in integration



$$M_{\text{top}} = 172.7 \pm 1.8 \text{ (stat)} \\ \pm 1.2 \text{ (syst)} \text{ GeV/c}^2$$

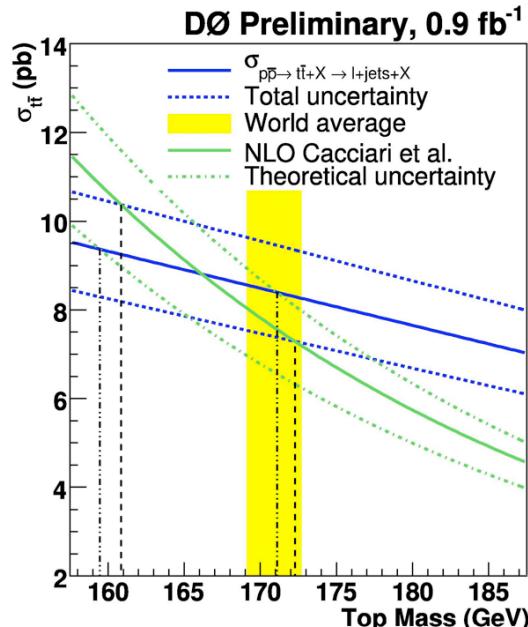
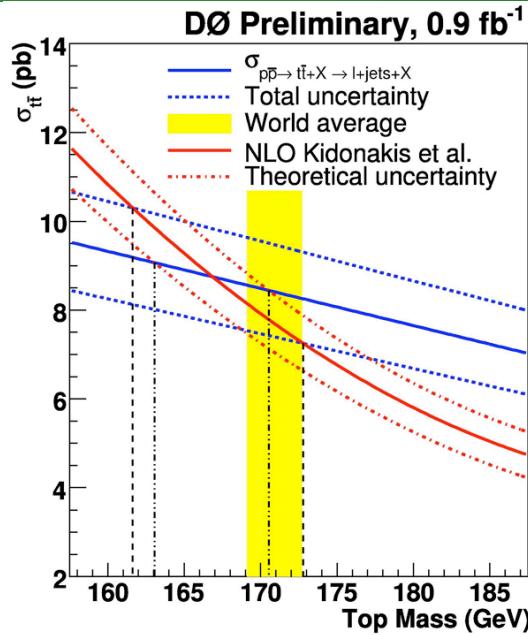
Example of systematics

Systematic	LJ	DIL	Combination
b-JES	0.6	0.5	0.6
Residual JES	0.5	3.5	0.5
ISR	0.3	0.4	0.4
FSR	0.2	0.5	0.2
PDFs	0.3	0.5	0.3
Generator	0.2	0.8	0.2
LJ bkgd shape	0.2	0.0	0.2
DIL bkgd shape	0.0	0.4	0.1
MC statistics	0.1	0.2	0.1
lepton energy scale	0.1	0.4	0.1
pileup	0.1	0.1	0.1
gg fraction	0.0	0.2	0.0
Combined	1.0	3.8	1.0

- Systematics (in GeV/c^2) from CDF Lepton+Jets and Dilepton template measurements
- In the process of revisiting all of these numbers
 - Trying to understand similarities, differences between CDF and DZero procedures

DZero Mtop from Lepton+Jets XSection

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- Pair production cross section depends on top mass
- Measurement of mass using xsection makes very different assumptions than other analyses
 - Require b-tag, at least 3 jets
 - Needs input from theory!

$$M_{top} = 166.9 +5.9/-5.2 \text{ (stat+syst)}$$

$$+3.7/-3.8 \text{ (theory) GeV/c}^2$$

theory: Kidomakis and Vogt

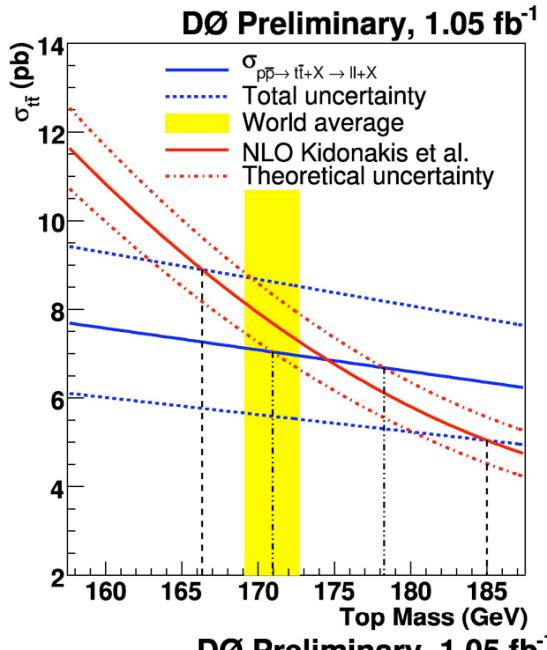
$$M_{top} = 166.1 +6.1/-5.3 \text{ (stat+syst)}$$

$$+4.9/-6.7 \text{ (theory) GeV/c}^2$$

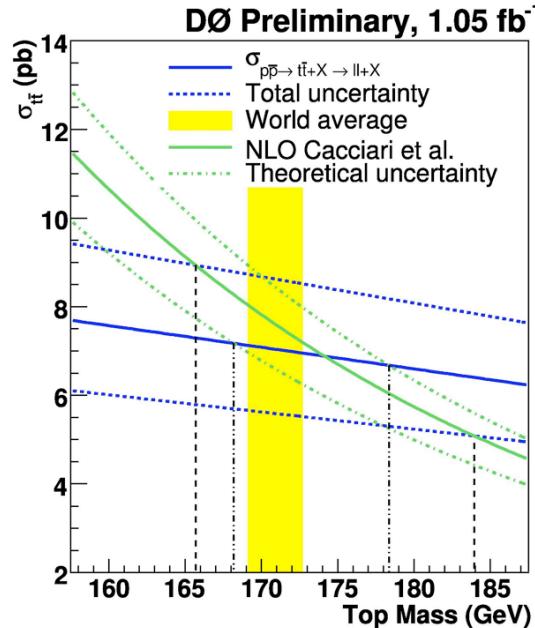
theory: Cacciari et al.

DZero Mtop from Dilepton XSection

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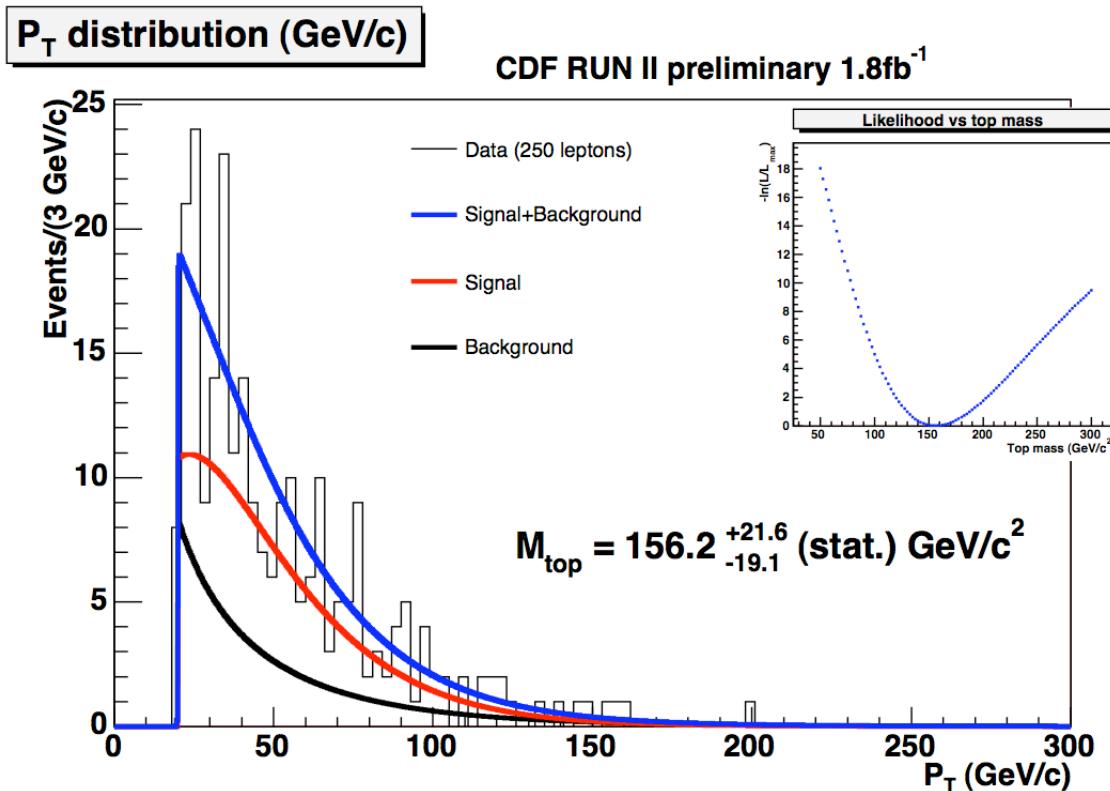
- Dilepton branching fraction smaller \rightarrow larger uncertainty on top mass



$M_{\text{top}} = 174.5 +10.5/-8.2 \text{ (stat+syst)}$
 $+3.7/-3.7 \text{ (theory) GeV/c}^2$ theory:
 Kidomakis and Vogt

$M_{\text{top}} = 174.1 +9.8/-8.4 \text{ (stat+syst)}$
 $+4.2/-6.0 \text{ (theory) GeV/c}^2$ theory:
 Cacciari et al.

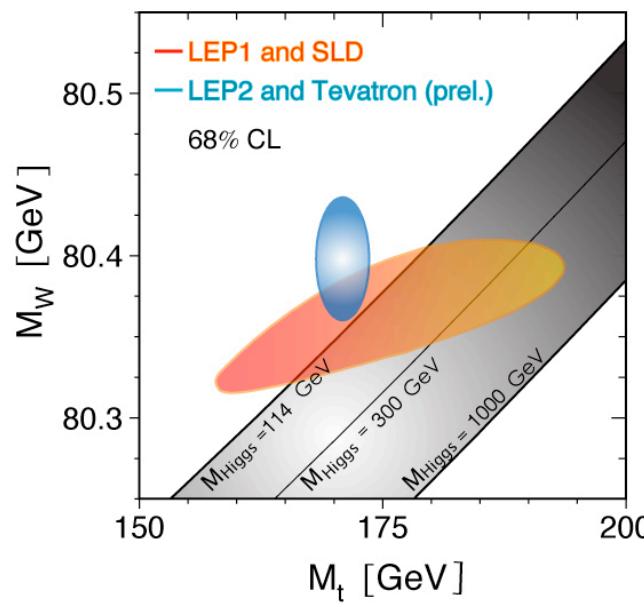
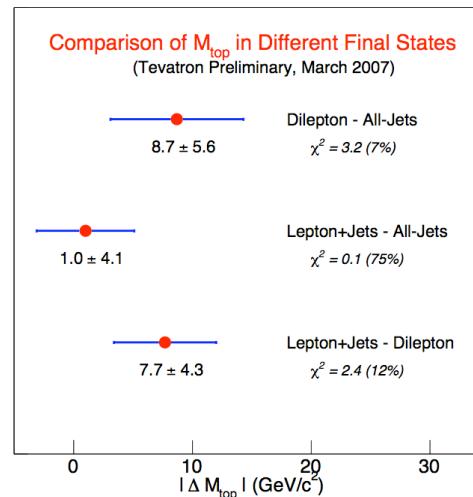
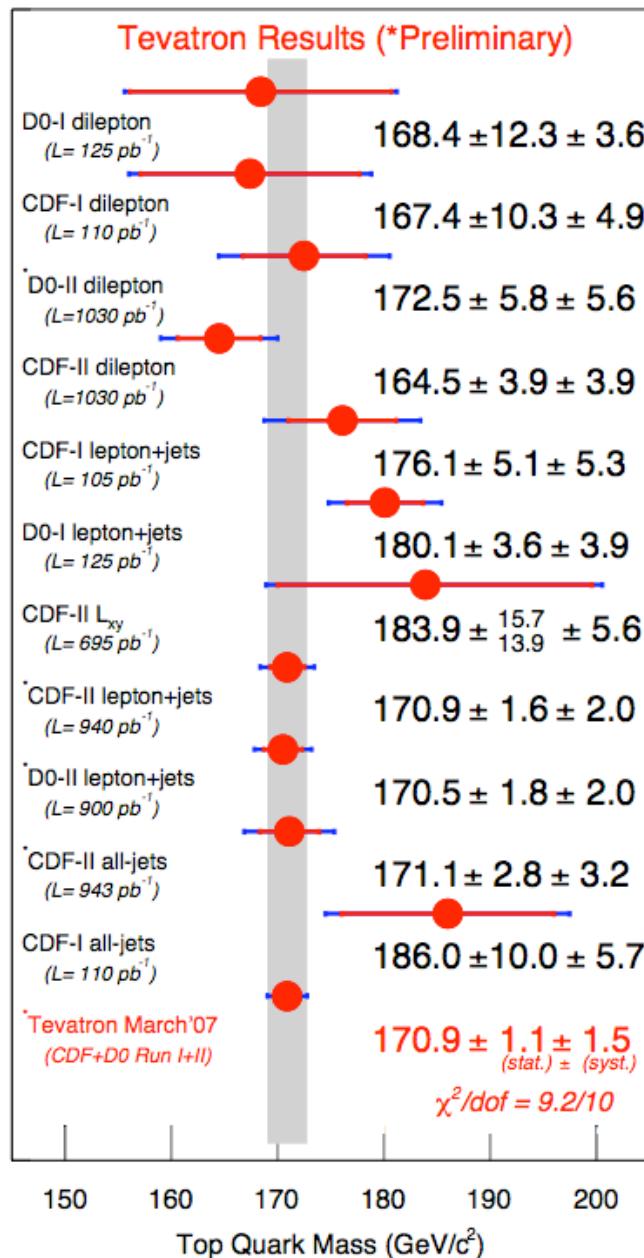
CDF Dilepton Pt



- Lepton from W decays get larger boost with increasing top mass
- Measurement very statistical limited, but good practice for LHC
- Systematics largely uncorrelated to JES

$$M_{\text{top}} = 156 \pm 20 \text{ (stat)} \pm 4.6 \text{ (syst)} \text{ GeV}/c^2$$

Tevatron Combination



- Combination last done 1 year ago
- Good agreement between different channels and across measurements!

**$M_{\text{top}} = 170.9$
 $\pm 1.1 \text{ (stat)}$
 $\pm 1.5 \text{ (syst)}$
 GeV/c^2**